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The Marine Corps needs to invest more time and effort in developing the capabilities of air-based logistics in order to reduce the exposure of ground-based logistics to threats and meet the sustainment needs of remotely deployed units. Based on weight alone, Air Delivery cannot completely replace ground-based logistics. However, with improvements in precision guidance, weight capacity of delivery systems, and improved recovery techniques, air delivery can have a major impact on logistics operations while lessening the exposure of ground-based logistics personnel and vehicles to enemy threats.

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MASTER OF MILITARY STUDIES

TITLE:

Air Delivery and Marine Corps Logistics

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Executive Summary

Title: Air Delivery and Marine Corps Logistics

Author: Major Richard C. Roberts, United States Marine Corps

Thesis: The Marine Corps needs to invest more time and effort in developing the capabilities of air-based logistics in order to reduce the exposure of ground-based logistics to threats and meet the sustainment needs of remotely deployed units.

Discussion: The purpose of this paper is to discuss the various means of logistics sustainment for the Marine Corps, and bring attention to the use of air delivery. Specifically, the intent is to answer the question: To what extent can air delivery be used to satisfy the logistics needs of remote units in the Afghanistan theater of operations. To address this question, the study examines the threat to ground-based logistics, the evolution of ground-based vehicles to counter the threat, and the lift capacity of air and ground vehicles organic to the Marine Corps. An examination of the emerging technologies in air delivery is conducted as well, to demonstrate the future of air-based logistics. Finally, a comparison of air and ground-based logistics is conducted to identify advantages and disadvantages in the areas of weight capacity, terrain, distance, cost, and number of personnel involved. The study concludes while proposing three main arguments. First, the Marine Corps needs to invest more time and effort in developing precision and low cost air delivery methods. Through advanced air delivery, the Marine Corps can better meet the needs of units deployed in austere environments. Second, the Marine Corps needs to develop a better method of recovering air delivery systems after use. Precision-guided systems are expensive but reusable. The use of ground-based recovery defeats the purpose of minimizing threat exposure. A vertical lift capable unmanned aerial system is a likely candidate to meet this recovery need. Finally, air-based logistics cannot completely replace ground-based logistics, but advancements in the areas discussed above will greatly improve the delivery capabilities while augmenting traditional logistics.

Conclusion: Based on weight alone, Air Delivery cannot completely replace ground-based logistics. However, with improvements in precision guidance, weight capacity of delivery systems, and improved recovery techniques, air delivery can have a major impact on logistics operations while lessening the exposure of ground-based logistics personnel and vehicles to enemy threats.

DISCLAIMER

THE OPINIONS AND CONCLUSIONS EXPRESSED HEREIN ARE THOSE OF THE INDIVDUAL STUDENT AUTHOR AND DO NOT NECESSARILY REPRESENT THE VIEWS OF EITHER THE MARINE CORPS COMMAND AND STAFF COLLEGE OR ANY OTHER GOVERNMENTAL AGENCY. REFERENCES TO THIS STUDY SHOULD INCLUDE THE FOREGOING STATEMENT.

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Preface

The basis for the thesis behind this paper comes mostly from personal experience. As a KC-130 Weapons and Tactics Instructor and Air Delivery Instructor, I have conducted air deliveries in training and while deployed for Operation Iraqi Freedom. These air deliveries used both conventional and precision-guided parachute systems. The KC-130 community, guided by Marine Aviation Weapons and Tactics Squadron One, has developed valid tactics, techniques, and procedures for delivering sustainment items when and where needed, while mitigating the risks and threats to aircraft and crew. Developing better technology to allow standoff, precision-guided delivery of logistics, can further reduce the threat and mitigate risk. Cheaper, more efficient and higher-weight capacity delivery systems are required in order for air-based logistics to have a major impact. However, the development of these systems will be pointless if a more efficient recovery mechanism is not developed at the same time. To this author, the vertical lift unmanned aerial system is the logical candidate. By combining precision-guided air delivery with vertical-lift unmanned aerial systems the Marine Corps can make a huge step forward in conducting and sustaining distributed operations.

As a Forward Air Controller (FAC) assigned to First Battalion, Seventh Marines, I have also been on the receiving end of a long logistics train. I was attached to what would be considered an enhanced infantry company that conducted distributed operations from a lone outpost on the border of Syria. We were at the tip of the spear for the battalion, and hence, at the end of the logistics train. The battalion pushed all logistics items to our location via ground convoy. Typically, this occurred on a two-week interval. When convoys arrived with much needed supplies and some luxury items, morale definitely improved. Having an efficient air delivery method that could sustain the base with several drops per week would have definitely helped sustain operations while keeping morale high.

While preparing for this paper, I relied heavily on personal knowledge and collaboration with peers. I owe a thank you to fellow KC-130 Weapons and Tactics Instructors who provided input to ensure the accuracy of my paper. Major Ryan Pope and Captain Christopher Kocab, USMC, are valued members of the fleet Marine force, and they provided valuable guidance for preparing this paper. My personal thanks also goes out to my Command and Staff Mentor, Dr. Edward Erickson, PhD. He provided clear guidance for developing a clear chain of thought within this paper, that I believe supports the thesis. Dr. Erickson also led me to explore the Khe Sanh sustainment effort in order to define the capabilities of the future. Without the support of these peers and my mentor, I could have never fulfilled my Master of Military Studies requirements.

Richard C. Roberts
Major USMC

Introduction

Marine Corps Order 4470.1 outlines the Marine Air Ground Task Force (MAGTF) deployment and distributions policy for the Marine Corps. This document defines the roles and responsibilities of the elements that make up the MAGTF. According to this document, one of the roles of the MAGTF logistic element, the Marine Corps Logistics Command (LOGCOM), is to act as the Marine Corps' distribution manager, with focus on point-of-origin to final destination movement and distribution support to the operating forces.[1] LOGCOM uses various modes of transportation to fulfill this role. Through land, air and sea based logistics; LOGCOM can fulfill the distribution requirements of the deployed forces. However, distribution is complicated and sometimes degraded due to the effects of enemy threat, terrain, weather, and infrastructure. In the Afghanistan theater for example, the use of improvised explosive devices (IEDs) and a lack of improved roads degrades the ability to provide sustainment for troops. An alternate means of distribution to supplement conventional over-the-road delivery is required.

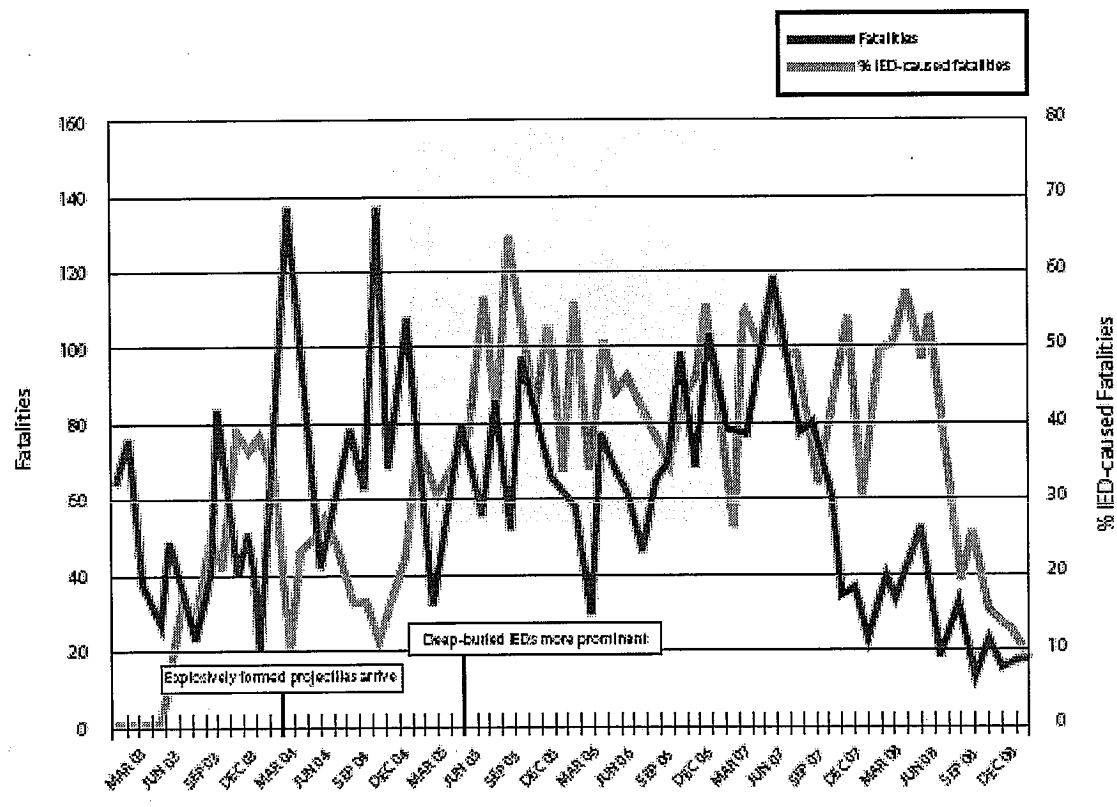
In order to discover an alternate means, one often has to look to the past. In 1968, the United States Marines and their South Vietnamese Army allies defended a small airstrip known as Khe Sanh. Much like some Afghanistan outposts, the airstrip was in a valley surrounded by mountainous terrain. Located in the Quang Tri Province of the Republic of Vietnam, the remote outpost was a key defensive base south of the Demilitarized Zone (DMZ), and a patrol and air base for conducting operations involving the border of Laos and the Ho Chi Min trail.[2] On January 21, 1968, the North Vietnamese Army (NVA) launched an offensive to seize Khe Sanh. The NVA cut off ground lines of communication and the outpost became isolated. Airland and air delivery was the only way to sustain the base. In February, the United States military demonstrated the capability to deliver more than 100 tons of resupply to the base with C-130, C-

123, and CH-53 aircraft.[3] Deteriorating weather, and enemy mortar threat to landed aircraft eventually drove the logistics effort more into air delivery operations. C-130 aircraft, using the Low-altitude Parachute Extraction System (LAPES) and conventional air delivery, dropped supplies to the airfield.[4] In one day in February, airdrops accounted for 80 short tons of supplies.[5] This airland and air-delivery re-supply effort would continue until a ground convoy was able to break through to the base. In the end, the emergency re-supply effort via airland and air delivery operations accounted for over 12,000 tons of cargo, with air delivery accounting for over 8,000 tons.[6] The future of air delivery and its impact on logistics was clearly apparent.

This paper will examine current Marine Corps air delivery (AD) capabilities and limitations to determine what extent AD can be used to supplement conventional logistics while satisfying the sustainment needs of remote units in the Afghanistan theater of operations. The study will identify the capabilities of organic Marine Corps AD platforms and systems as compared to the Marine Corps ground based vehicles, how they are exposed to threats, and make an argument for improving the AD capabilities in order to better serve the logistics needs of remote units. This paper will argue that the Marine Corps needs to invest more time and effort in developing the capabilities of air-based logistics in order to reduce the exposure of ground-based logistics to threats and meet the sustainment needs of remotely deployed units.

Threat to Ground-Based Logistics

The obvious threat to ground based logistics in the Afghanistan and Iraq theaters are the Improvised Explosive Device (IED). The IED is a leading cause of injury and death in both theaters, and the weapon of choice for insurgents.[7] In Iraq for example, IEDs were responsible for Fifty to Eighty percent of United States fatalities during the period from summer 2005 to spring 2008 (See figure 1). IEDs used against a logistics convoy have the capability of delaying delivery and destroying precious cargo. The insurgents have tailored these IEDs to inflict maximum damage to the vehicles used by coalition forces, and they continue to adapt to changes in coalition tactics, techniques and procedures (TTPs).



The box represents the roughly 2-year period before the 2007 "surge" when U.S. operational strategy was to reduce risks to U.S. forces and transfer security responsibilities to Iraq.

Sources: Michael E. O'Hanlon and Jason Campbell, *The Iraq Index* (Washington, DC: The Brookings Institution), available at <www.brookings.edu/FP/saban/iraq/index.pdf>; Defense Manpower Data Center, Statistical Information Analysis Division, available at <http://siadapp.dmdc.osd.mil/personnel/CASUALTY/OIF-Total-by-month.pdf>; Andrew Feickert, *Mine-Resistant, Ambush-Protected (MRAP) Vehicles: Background and Issues* (Washington, DC: Congressional Research Service, 2007), available at <http://fas.org/sgp/crs/weapons/RS22707.pdf>; and various reports from *Defense News*, *The New York Times*, DefenseLink, and *The Washington Post*.

Figure 1 (Percentage of IED-caused Fatalities and Total Fatalities for Iraq Theater)[8]

In response, the Department of Defense has spent billions on new equipment to combat the IED. Up-armored High Mobility Multipurpose Wheeled Vehicle (HMMWV or Humvee) replaced the unarmored Humvees to combat explosives tossed under moving vehicles by insurgents. The insurgent adapted to this change by using larger, more powerful IEDs burried in and on the sides of roadways, and by using explosively formed penetrator (EFP) IEDs. The EFP acts as a shape charge capable of penetrating armor and spraying shrapnel throughout the vehicles interior.[9] These more powerful IEDs caused an increased surge in casualties (See figure 2), and led to the development and fielding of the Mine Resistant Ambush Protected (MRAP) vehicle.

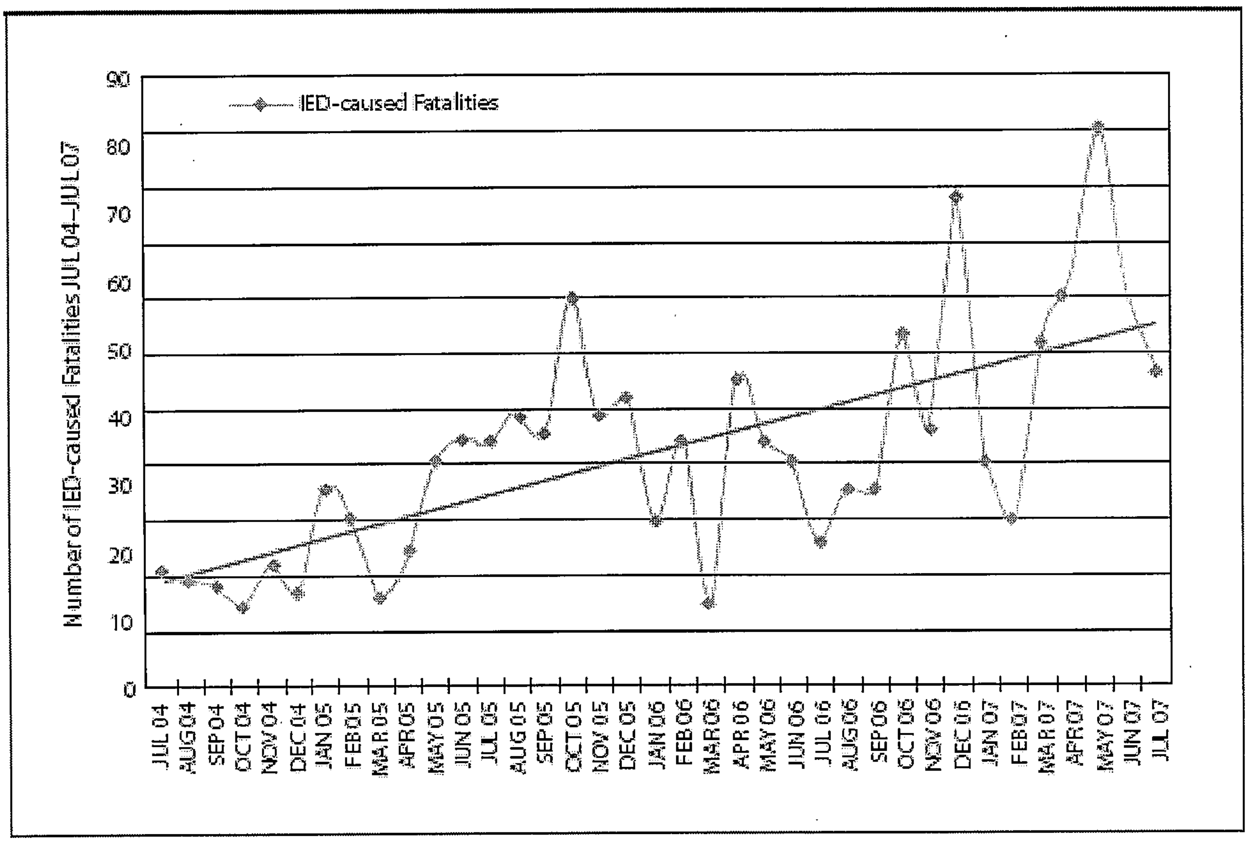


Figure 2 (Trend line for IED Fatalities Before the Surge and MRAP Deployments in Iraq)[10]

It should be noted that the data concerning IED fatalities shown above is limited to the Iraq conflict. This information is used in this discussion for two reasons. One, the Iraq war was at the forefront for US involvement since it began in 2003. The bulk of US troops were deployed to Iraq, conducting more operations, and requiring a larger logistics footprint than Afghanistan. This large footprint and the heavy reliance on ground-based logistics led to the development of the MRAP as discussed above. Currently, the US forces in Iraq have been drawn down and shifted over to the Afghanistan theater. This increase in personnel in Afghanistan will have an increased logistics requirement as well. This will result in more ground-based logistics convoys, which are exposed to IED and ambush tactics used by insurgents. Secondly, the use of IEDs in Afghanistan will most likely increase. The road network in Afghanistan is more limited than Iraq, making travel more predictable and restricted. Plus, the Afghanistan insurgent will most likely use IED and ambush tactics more to conduct irregular warfare much like the insurgent in Iraq. For this reason, the data from the Iraq theater concerning IEDs and the similar conditions in Afghanistan as a result of the surge in forces, is valid for making a comparison.

The MRAP has proven very effective at protecting its occupants from IED strikes, put is still vulnerable to damage. It also brings other problems to the battlefield like its maneuverability and weight issues. The vehicle is often too large to maneuver through tight alleys and congested roads. Weighing in at over 40,000 pounds, the MRAP also cannot travel on many of the roads and bridges found in Iraq and Afghanistan. Additionally, it offers the MAGTF only limited expeditionary capability due to the fact it cannot be transported on Navy Landing Helicopter Dock (LHD) / Landing Helicopter Assault (LHA) ships, cannot fit in the cargo department of a C-130, and cannot be lifted by a CH-53.

The MRAP is also hindered by its offroad capability. Because of its limited ability to travel offroad and traverse steep grades, the Marine Corps was forced to look for an alternative. The Mine-Resistant, Ambush-Protected All-Terrain Vehicle (M-ATV) was created to meet this challenge. However, the Marine Corps has opted to go with an upgraded, independent suspension system for the original MRAP Cougar. This suspension, modeled after the successful TAK-4 system used on the 7-ton truck, improves the MRAP's ability to travel off-road, but does nothing to answer the weight issues. Based on reducing the weight, the M-ATV is the logical candidate for replacing the Humvee in the future as technology improves to meet the needs.

The discussion of MRAPs and M-ATVs is included here because of their use as escort for logistic convoys. They are used to transport security and quick reaction forces, and to a lesser extent for transporting actual cargo. The mainstay for cargo transportation is the Medium Tactical Vehicle Replacement (MTVR or 7-Ton) and Logistics Vehicle System (LVS) or Logistics Vehicle System Replacement (LVSR) vehicles. These vehicles have not undergone significant replacement to date, but do have various armor upgrades designed to protect the occupants. These upgrades do little to protect the vehicle and cargo from damage, however, and more on this subject will be discussed later.

Marine Corps Organic Logistics Capabilities

This study will now focus on Marine Corps organic logistics capabilities to establish baseline capacities and capabilities. We will focus on conventional over-the-road vehicles and AD capable vehicles. Specific lift capacities will be cited to establish a baseline for comparison between ground-based and air-based logistics. For a snapshot of lift capacities, refer to the table at the end of this section.

The Marine Corps has two primary logistics vehicles in its inventory for over-the-road, conventional delivery of logistics items, the LVS or LVSR, and the MTVR. The Marine Corps also maintains a fleet of 5-ton trucks and various utility trailers to augment the heavy load carriers. For transporting heavy equipment like tanks, loaders and dozers, the Marine Corps uses the Military Heavy Equipment Transport (MHET). For fuel transport, the Corps relies on the M-969, M-970 & MK-970 family of Semi-Trailer Refuelers. This paper will focus on the capabilities and limitations of the LVSR and MTVR as well as the Semi-trailer refuelers. These vehicles are the primary cargo and fuel handling vehicles in competition with AD.

Employed in three separate variants, cargo, tractor, and wrecker, the LVSR replaces the 25-year-old LVS. It has factory installed armor as well as after market armor kits that can protect the vehicles occupants. For improved off-road capability over the LVS, Oshkosh Defense added an independent TAK-4 suspension system, as well as rear wheel steering. The LVS MKR18 Cargo variant has a curb weight of 53,700 pounds and a Gross Vehicle Weight Rating (GVWR) of 106,000 pounds.[11] With the installation of various survivability and performance kits this equates to a payload capacity of 45,000 pounds on-road, and 33,000 pounds off-road based on load handling ability.[12]

The MTVR is the primary logistic vehicle for the Marine Corps, and is the replacement for the aging 5-ton truck fleet. The MTVR is a very capable off-road vehicle due to its TAK-4 independent suspension system, electronically controlled engine and transmission, and central tire inflation system. However, the MTVR does not come from the factory as an armored vehicle. The MTVR is a Ready to Accept Armor (RTAA) vehicle that requires after market installation of armor.[13] The MTVR has a Curb Weight of 29,100 pounds and a GVWR of

62,200 pounds. The MTVR has a cargo capacity of 30,000 pounds on-road and 14,000 pounds off-road.[14]

To protect the occupants and cargo of the MTVR, Oshkosh developed the MTVR Armor System (MAS) kits. The MAS kit can provide side, overhead, and underbody protection for the crew compartment utilizing Mil-A-46100 High Hard Steel and Metal Composite. With a weight of 10,500 pounds, the armor kit increases the overall weight of the MTVR.[15]

As stated earlier, the Marine Corps relies primarily on the MK970 5000 Gallon Semi-Trailer Refueler for transporting bulk fuel. This vehicle is designed like the LVSR with similar armor and off-road capabilities. For protecting the fuel, the tanks can be covered with a self-sealing, balistic coating developed by VSE Corporation. This Tanker Balistic Protection System (TBPS) provides small arms and shrapnel protection to the mobile tankers. This system is vital to the survivability of over-the-road fuel transport in a combat environment.[16]

On the aviation side, the Marine Corps relies primarily on the heavy lift capacities of the KC-130 transport aircraft and the CH-53 helicopter. The MV-22 tiltrotor and CH-46 helicopter are also used to a lesser extent for logistics support. Each aircraft has different and specific capabilities that can be leveraged to support the MAGTF.

The aircraft with the largest lift capacity and most versitile AD capability is the KC-130 Hercules. The maximum lift capacity will be limited by factors such as runway available, climb gradient required, and fuel on board. Depending on these parameters, the KC-130 can carry anywhere from 20,000 to 42,000 pounds of cargo.[17] With the capability to land on short, unimproved airstrips, and stretches of highway, the KC-130 can also deliver cargo in austere environments via airland operations.

The KC-130 is also capable of delivering cargo and fuel via AD parachute systems. Two primary types of cargo AD exist, Heavy Equipment (HE) and the Container Delivery System (CDS).[18] Door bundles consisting of up to 500 pound containers may also be dropped for tailored logistics, but this is not a primary means of delivery. HE loads consist of cargo weighing between 2,520 pounds and 42,000 pounds, but maximum weight is limited based on factors discussed in the previous paragraph. CDS is designed to deliver sixteen or fewer A-22 containers which can weigh up to 2,200 pounds per container (2,322 pounds weight rigged). Two A-22 containers can also be married together to allow up to 4,656 pounds per married container for AD of larger items.[19] For fuel delivery, rubber fuel bladders called blivets, with a fuel capacity of 3,400 pounds (500 gallons)[20], can be dropped from KC-130 aircraft via CDS or HE operations.

For airland-fuel transport, two primary options exist for the logistician. If an outpost is co-located with an airstrip rated for C-130 landings, fuel can be delivered via wet-wing or through the use of the Aerial Bulk Fuel Delivery System (ABFDS). Using the wet-wing method allows the C-130 aircraft to land, and transfer fuel that is carried in the wings of the aircraft, or in a fuselage fuel tank carried in the cargo compartment, to the ground station fuel bladders or vehicles. Virtually all the fuel that is carried can be transferred, but it must be noted that this is the same fuel the aircraft uses for its engines. Fuel that is needed for the flight back from the outpost cannot be transferred to the ground fuel bladder. The ABFDS consists of a 3,000 to 24,000 gallon fuel bladder that can be transported on C-130 aircraft. However, the ABFDS is not very efficient due to time and personnel involved for install and removal.[21] The most efficient means of fuel transfer is through the use of wet-wing, and this will be discussed further.

The USMC KC-130 with external wing tanks, a fuselage tank, and air-to-air refueling pods installed can carry 58,466 pounds (8,598 gallons) of fuel in its wings, and an additional 24,392 pounds (3,587 gallons) of fuel in the fuselage tank, for a total fuel weight of 82,858 (12,185 gallons). These weight limits correspond to high-strength runways. For marginal strength runways which would be typically found at remote or expeditionary airfields, the weights are reduced. Only 39,628 pounds (5,827 gallons) can be carried in the wings for maximum-effort landings at marginal strength airfields, and the fuselage weight will be limited based on the weight bearing capacity and runway length / aircraft landing performance parameters.[22]

As noted earlier, this fuel can be either transferred or burned by the aircraft's engines. The amount of fuel available for offload at the outpost will depend on the distance the aircraft has to fly after leaving the outpost and the length and weight capacity of the airfield at the outpost. For planning purposes, the Marine Corps has established the standard minimum operating strip with dimensions of 5,000 feet long by sixty feet wide.[23] For demonstration purposes we will use this airfield length, with sufficient weight bearing capacity, to establish a fuel offload capacity for the KC-130. With the given runway available, and a 1 hour flight requirement after offload, the KC-130 can typically offload up to 45,000 pounds (6,617 gallons) of fuel.[24]

For vertical lift, the Marine Corps relies on the MV-22 tiltrotor, the CH-53, and the CH-46 aircraft. All are capable of parachute delivery, but are used primarily for airland logistics. This paper will focus on this airland capability for determining lift capacity. As with the KC-130, the lift capacity will depend on parameters such as airfield elevation, outside air temperature, density altitude, and fuel state. The MV-22 has the ability to externally lift 10,000 pounds via cargo hooks, and can AD 2,500 pounds.[25] The CH-53E[26] model can lift 32,000 pounds of cargo externally.[27] Due to its external lift capability and its ability to land in austere environments, the CH-53 does not typically conduct cargo AD.[28] As for the CH-46, it has a lift capacity of 4,000 pounds,[29] and like the CH-53, does not conduct AD on a normal basis. For a breakdown and comparison of Marine Corps organic lift capacities refer to table 1 below.

Vehicle	Lift Capacity (Pounds)
LVSR	45,000 (33,000)*
MTVR	30,000 (14,000)*
MK970	5000 gallons
KC-130	20,000 - 42,000 HE / 35,200 CDS / 500 Door Bundle / 6,617 gallons of fuel
CH-53E	32,000 / 2,400 gallon TBFDS
MV-22	10,000 / 2,500 AD
CH-46	4000
	* Number in () = Off-road capability

Table 1: (Marine Corps Organic Lift Capacity)

Threat to Air-Based Logistics

Now that the foundation has been established for Marine Corps cargo delivery, we can focus on emerging technologies for AD, and conduct a comparison of ground and air delivery capabilities. However, we have already discussed the threat to ground-based logistics, so we need to discuss the threat to air-based logistics.

Surface-to-Air Missiles (SAMs) or the Man-Portable-Air-Defense-System (MANPAD), as well as small arms, machine guns, Anti-Aircraft Artillery (AAA) and rocket-propelled grenades are the primary threats to aircraft in the Iraq and Afghanistan theaters. MANPADs like the SA-7, SA-16 and SA-18 have significant lethality against aircraft, but have not been successfully used as often as other hostile fires. However, the proliferation of SA-7 MANPADs throughout the Middle East Region will continue to make MANPADs an area of concern. These missiles have the capability to inflict significant damage to aircraft, and can cause catastrophic loss if successfully employed. To date, the catastrophic loss to aircraft due to hostile fires is significantly less than the damage inflicted to ground vehicles by IED's. Aircraft have on board defensive systems that can defend against SAMs and can rely on tactics, techniques, and procedures to avoid other ground threats. Compared with the threat to ground vehicles, aircraft are exposed to fires less often, and have had much greater success in defeating these threats.

Emerging Technologies and Capabilities of Air Delivery

Today, accuracy is one parameter that hinders the capabilities of AD. In order to lessen the drop zone requirements and increase the accuracy of the landings unguided parachutes are dropped at altitudes from 400 to 1,000 feet above ground level. Dropping at these altitudes exposes aircraft to surface fires and SAMs. AD conducted at higher altitudes can minimize threat exposure, but the result is a very large drop zone requirement and decreased accuracy due to variables like free-fall, drift-under-canopy, and wind changes at different altitudes. To minimize threat exposure and still provide accurate delivery of cargo, precision-guided, steerable parachute systems or other alternatives that are more accurate are required.

Several precision systems are in development. These systems include the Precision Extended Glide Airdrop System (PEGASYS)[30], Joint Precision Air Delivery System (JPADS)[31], and Sherpa-guided Parachute Air Delivery System (SHERPA)[32]. These precision-guided delivery systems take advantage of a steerable parachute and direct it to the drop zone with GPS guidance. Alternatives to guided parachutes in development include unguided High-velocity (Hi-V) CDS and High-Altitude-Low-Opening (HALO) CDS[33]. These systems use increased rate-of-fall characteristics to minimize time under canopy and reduce the impacts of drift. The Marine Corps should also invest effort into improving the maximum weight capacity of CDS by exploring the use of the Enhanced CDS (ECDS) system developed by the Army. While the current CDS can handle only 2,200 pounds per container, the ECDS has a projected weight capacity of 10,000 pounds. These 10,000-pound containers can provide precise delivery to remote units when coupled with JPADS and GPS.

The future of AD depends on the development of these more advanced systems that make AD more precise and more efficient. The Marine Corps has focused efforts on developing precision-guided AD systems like JPADS and SHERPA, but has not focused on the recovery of these systems. The Marine Corps must develop an efficient means of recovering parachute systems in order for precision-guided delivery systems to be effective. Because of the cost of these systems, the recipients cannot abandon them. This is why the Marine Corps must develop the use of a Vertical Takeoff and Landing Unmanned Aerial Vehicle (VTUAV). VTUAVs like the Boeing A160 Hummingbird, Bell Helicopter Eagle Eye, and the Northrop Grumman RQ-8A Fire Scout are leading the industry, but these systems are primarily Aerial Sensor systems. With a lift capacity of less than 300 pounds, they fall short of the vertical lift capacity for tailored logistics.[34] By developing a UAS with vertical lift capability, the Marine Corps can tailor the delivery of immediate or on-call sustainment items, and as a secondary mission, recover the guidance systems used for precision AD systems. To accomplish this, the VTUAV would need to have sufficient lift capacity for the weight of the guidance systems and parachutes. For example, one JPADS parachute and guidance assembly weighs 150 pounds.[35] To recover sixteen JPADS previously dropped by a KC-130, a VTUAV would have to lift 2,400 pounds. The Marine Corps must also establish procedures for the storage, packing and loading of AD systems by the receiving unit. By using VTUAVs as a recovery system, precision-guided AD has a greater potential for success.

The Logistics Requirement

Before we begin a comparative discussion, we must first establish the requirement for logistics. For this paper, we will use the Marine Rifle Company as the baseline, with a total of 150 Marines.[36] We will use water, a precious commodity in all environments, as our sustainment item. We will base the requirement on three days of supply (DOS) of water for drinking purposes only. Based on an arid/hot climate, a single Marine requires three gallons of water per day (G/P/D)[37]. A rifle company of 150 Marines requires 450 G/P/D or 1,350 G/P/D for three DOS. At a weight of 8.4 pounds per gallon, a rifle company requires 3,780 pounds of water per day and 11,340 pounds of water for three DOS. For simplicity, these figures do not reflect the weight of the water containers, which would vary by manufacturer and container.

Air versus Ground: A Comparative Discussion

Based on the requirements for water established above, this study will now conduct a detailed analysis of the transportation capabilities of the Marine Corps. We will discuss the ground-based logistics vehicles of the Marine Corps versus the aviation assets of the Marine Corps. Weight is the primary factor for discussion, but we will discuss terrain, distance, cost, and number of personnel involved here as well. We will assess each capability as either a ground advantage or an aviation advantage.

Lift Capacity: A Ground Advantage

Based on the weight factor alone, ground-based logistics is the obvious winner. A logistic convoy with six MTVRs and three LVSRs can carry 183,000 pounds of cargo off-road. It would take approximately five KC-130 aircraft, or six CH-53E helicopters to carry this same amount. However, when we use the water example as discussed above, it only takes one MTVR or one CH-53E to carry three DOS of water. A KC-130 can conduct a single AD mission to drop a single HE container or six CDS containers with three DOS of water as well. From a weight standpoint only, neither ground-based nor air-based vehicles have an advantage when the requirement is to deliver three DOS of water for a remote infantry company.

As for fuel requirements, ground-based logistics has the advantage unless there is a KC-130 supportable airstrip at the outpost. The amount of fuel a KC-130 can offload is equal to or exceeds that of the MK970 5000 gallon tanker. The KC-130 can delivery fuel more efficiently and in greater amounts than ground-based transports. However, the need for improvements exists if the outpost has to rely on air delivery for fuel. Until a larger capacity fuel bladder rated for AD is developed, ground-based logistics will be required.

Threat Exposure: Aviation has the Advantage

Aviation wins the edge when considering the amount of time spent exposed to enemy threats. Enemy fire threatens logistics convoys more often and for a longer time. Using on-board survivability assets and proven tactics, aviation assets can avoid or minimize exposure to most enemy threats in the Afghanistan theater. The development of precision AD systems will further minimize the exposure to threat based on the increased standoff and altitude capabilities these systems allow.

Terrain: Advantage Goes to Aviation

The off-road capability of ground vehicles is the deciding factor concerning terrain. In a rocky, high-desert environment like Afghanistan where there is only a small amount of improved roads and bridges, vehicle travel is very limited. Terrain may also force ground vehicles to travel predictable routing increasing the likelihood and lethality of enemy actions. Moreover, for operations conducted in high, mountainous terrain where vehicles cannot go, aviation is the only option.

Distance: Aviation has the Advantage

Infantry companies placed at the tip of the spear can be hundreds of miles away from the Main Logistics Base (MLB). For example, in order to resupply a company that is 150 miles from the MLB, it would take a ground convoy upwards of four hours to traverse the distance. Aviation assets can cover this distance in less than one hour, effectively making several deliveries before ground vehicles can make one.

Financial Cost: A Ground Advantage

The cost of delivery is a key factor for consideration. Aviation-based logistics may not be cost effective based on operating costs alone. The KC-130 for example has a $5,380 planned cost per hour[38] to operate, which is considerably more than ground logistics vehicles. In addition, conventional and precision-guided AD systems are expensive. As discussed earlier, if recovery of delivery systems is not completed the AD cost effectiveness would be significantly degraded.

Personnel Involved: Aviation has the Advantage

The number of personnel exposed to enemy threat in a logistics convoy is much greater than the number involved in AD. Using the same convoy example in the lift discussion, a convoy consisting of six MTVRs and three LVSRs would require 27 Marines just for the cargo vehicles alone. This convoy would most likely require a platoon size element of Marines in MRAP or other vehicles to provide security. Conversely, a KC-130 crew consists of only five Marines for conducting AD. A division of three KC-130s with five Marines per aircraft could deliver the same amount of cargo as the ground convoy discussed here, while exposing only 15 Marines to an enemy threat that is minimal in Afghanistan.

Based on the above discussion, the primary disadvantage of aviation-based logistics is cost. Cost directly relates to recovery of delivery systems and the associated cost per hour to operate. The Marine Corps cannot change the cost per hour factor easily, but can affect the recovery of delivery systems. Currently, ground vehicles recover parachute systems used in theater. Alternatives to ground vehicle recovery includes helicopter pickup or the development and use of a vertical lift UAS. The UAS is a logical solution to the recovery of AD systems once a vertical takeoff and landing UAS is developed. Until then, we will have to rely on conventional recovery of AD systems.

It is clear from the discussion here, that aviation has several advantages over ground-based logistics. However, aviation cannot replace ground-based logistics all together. As a supplemental tool for logisticians, aviation has several key aspects that can be leveraged. The primary advantage of AD is the ability to maximize the amount of personnel and equipment delivered to a forward location in a short period of time. This delivery is accomplished with less exposure to enemy threat, with less personnel involved, and where terrain has little to no impact.

The Way Ahead

In December of 2008, General James T. Conway, Commandant of the Marine Corps, described the concept of Enhanced Company Operations (ECO) and issued challenges for Marine Corps Combat Development to explore this theory further. The Commandant envisioned ECO as a "company-size MAGTF" capable of maximizing the "tactical flexibility offered by true decentralized mission accomplishment, consistent with commander's intent and facilitated by improved command and control, intelligence, logistics, and fires capabilities."[39] The intent of ECO is to allow the distribution of company-size units throughout the battle space and achieve tactical success in an austere, expeditionary environment. To sustain this fast-moving force, enhanced logistics capabilities are required. AD has the capability to meet this need, with sustainment through "tailored re-supply" at the right place and time.

The Marine Corps needs to improve current technology in order to meet the requirements of logistics in austere environments. The Marine Corps must focus on disposable or low cost AD systems and unmanned delivery vehicles. KC-130 and MV-22 aircraft can be used to provide precision AD of sustainment items, while unmanned aerial vehicles can be used for small, tailored bundles. The unmanned vehicles can also pick up delivery parachutes and equipment used to drop the heavier items.

The battlefield of the future would consist of several company-sized units, distributed in austere locations, conducting mounted and dismounted patrol. KC-130 aircraft will deliver pre-planned, heavy sustainment items via GPS guided CDS (SHERPA or JPADS). MV-22, CH-53 and unmanned aircraft will deliver pre-planned and immediate items. These same unmanned vehicles and helicopters recover the GPS equipment and parachutes previously delivered by KC-130 aircraft. The unmanned vehicles return this equipment to the logistics bases, where the process begins all over again.

To further define the requirement and a possible solution we will use an example based on a Marine Rifle Company conducting Distributed Operations in Afghanistan. We will divide the operation into phases and discuss the possible actions that could occur during phases using ground and aviation assets to support this operation.

Phase I: Seize the Objective

During this phase, CH-53, MV-22, or CH-46 aircraft transport assault forces in order to seize the objective. The KC-130 is used to deliver paratroops if necessary, and provide a platform for Airborne Mission Commander / Radio relay.

Phase II: Consolidation on the Objective

During this phase, ground vehicles transport the follow on forces to the objective along with necessary sustainment items. This initial logistics / re-enforcement convoy would consist of MTVR, LVSR, and MRAP vehicles. Six days of supply of food, water, ammunition, etc. would be included in this convoy.

Phase III: Precision Re-supply

At this point, the forward-deployed company would request logistics support through the normal chain. The unit providing the logistics support determines the method. If air delivery is feasible, the logistician submits an Assault Support Request (ASR) to the supporting air wing. An Air Tasking Order (ATO) would direct the appropriate unit and aircraft to fulfill the ASR. A KC-130 aircraft, for example, would then deliver sustainment logistics via precision-guided CDS. The company on the ground would retain the delivery systems for later pickup.

Phase IV: Tailored Re-supply

In this phase, and the next, logistics remains tied to the air tasking cycle. External loading of MV-22 or CH-53 aircraft accomplish on-call or immediate re-supply of sustainment items. More tailored items would be delivered via vertical lift UAS. These same UASs and helicopters would recover parachutes and guidance systems from the ground force. KC-130 aircraft conduct CDS airdrops of fuel blivets for sustainment.

Phase V: Sustainment

Delivery systems recovered by UAS in Phase IV are re-packed and fitted by the Air Delivery Platoon and subsequently delivered by KC-130. Ground forces would again retain all delivery systems.

Phase VI: Bulk Re-Supply and Recovery

Follow on logistic convoy would conduct bulk re-supply as required, and recover any delivery systems that had not already been recovered by UAS or helicopter. At the completion of this phase, a simultaneous, on-going logistic system as described above would continue to sustain the forward-operating force. By maximizing use of air delivery platforms and systems, the frequency of ground-based logistics trains is reduced, and the exposure of troops to ground threats is minimized.

Conclusion

The purpose of this paper was to discuss the various means of logistical sustainment for the Marine Corps, and bring attention to the use of air delivery. Specifically, the intent was to answer the question: To what extent can AD be used to satisfy the logistics needs of remote units in the Afghanistan theater of operations. Based on weight alone, AD will never be able to completely replace over-the-road delivery of logistics items. However, with continued improvement in AD systems, specifically precision systems, fuel delivery systems, and unmanned aerial vehicles, AD can supplement the traditional logistics train while bypassing the IED and ambush threat. As stated earlier, the IED has emerged as the weapon of choice for the current insurgency faced in Iraq and Afghanistan. If AD can be used to reduce the number of vehicle convoys on the road, and lessen the exposure of troops to this threat, the Marine Corps would take a great step forward in defeating the insurgency and be one step closer to withdrawing forces from Afghanistan and Iraq.

Endnotes

[1] HQ Marine Corps, Marine Corps Order 4470.1, *Marine Air Ground Task Force (MAGTF) Deployment and Distribution Policy (MDDP)*, p. 9

[2] Peter Bush, "Battle of Khe Sanh: Recounting the Battle's Casualties", Historynet.com, p. 1

[3] Message from General Westmoreland, COMUMACV to General Wheeler, CJCS: Airlift for the period of 041200H to 051200H Feb 1968 amounted to 128 tons.

[4] Major General McLaughlin, USAF, "Khe Sanh: Keeping an Outpost Alive"

[5] Text of Cable from General Westmoreland to General Wheeler, Thursday, February 16, 1968. "Khe Sanh was resupplied with 188 short tons during the period, with 80 short tons being air dropped from Air Force C-130 aircraft. Nineteen C-123 and helicopters air landed the additional 107.5 short tons. A total of 141 short tons of ammunition and 31 short tons of engineering equipment were included."

[6] Major General McLaughlin, USAF, "Khe Sanh: Keeping an Outpost Alive". At the conclusion of the 78-day emergency resupply of Khe Sanh, C-130s and C-123s had delivered a total of 12,430 tons of cargo, 8120 tons by airdrop and 4310 tons by airland.

[7] Christopher J. Lamb, "MRAPs, Irregular Warfare, and Pentagon Reform", JFQ / issue 55, 4th quarter 2009, p. 77

[8] Ibid.

[9] Ibid.

[10] Ibid. p. 79

[11] Oshkosh Defense Technical Data brochure for the LVSR.

[12] MARCORSYSCOM Technical Data Sheet for LVSR MKR18 Cargo Variant. Installation of armor, weapon mount, machine gun, ammo, run-flat and arctic kits increases Curb Weight to 64,125.

[13] MARCORSYSCOM Technical Data Sheet for MTVR MK23/MK25/MK25A1. MK23A1/MK25A1is referred to as "ready to accept armor" (RTAA). This model has upgraded cab mounts, armored flooring, upgraded suspension, and air conditioning. RTAA is not considered an armored vehicle and is interchangeable with the MK23/MK25 to satisfy (T/E) allowances.

[14] Oshkosh Defense Technical Data brochure for the MTVR.

[15] MARCORSYSCOM Technical Data Sheet for the MAS.

[16] Sylvia Gethicker, "Spirited VSE Employees in Iraq Help Provide Margin of Safety to Those Transporting Combustible Fuel", p. 10

[17] Department of the Navy, Naval Air Systems Command. *NATOPS Flight Manual: Navy Model KC-130J Aircraft*

[18] Marine Aviation Weapons and Tactics Squadron One (MAWTS-1). *Combat Aircraft Fundamentals KC-130 (Unclassified//For Official Use Only)*, p. 5-1

[19] Information derived from Department of the Navy, Naval Air Systems Command. *Technical Manual: Cargo Loading Navy Models KC-130F, LC-130F, LC-130R, KC-130R, KC-130J, C-130T, KC-130T, and TC-130G Aircraft*, and the Department of the Navy, Naval Air Systems Command. *NATOPS Flight Manual: Navy Model KC-130J Aircraft*

[20] Air Force Logistics Management Agency, *AEF Fuels Management Pocket Guide.* P. 50

[21] Air Force Logistics Management Agency, *AEF Fuels Management Pocket Guide.* p. 27-28

[22] Department of the Navy, Naval Air Systems Command. *NATOPS Flight Manual: Navy Model KC-130J Aircraft*, p. 4-2. KC-130 maximum landing gross weight for marginal strength airfields is 164,000 pounds. This weight includes the weight of the aircraft, crew, passengers, fuel, and cargo.

[23] Marine Aviation Weapons and Tactics Squadron One (MAWTS-1). *Combat Aircraft Fundamentals KC-130 (Unclassified//For Official Use Only)*, p. 6-1

[24] KC-130 with version 6.5 software upgrade is limited to a maximum landing weight of 164,000 pounds, and limited to 39,628 pounds of fuel in the wings (external tanks empty). At 164,000 pounds, the aricraft is capable of landing and coming to a stop on a 5,000 foot runway, provided the weight bearing capacity is sufficient. With only 39,628 pounds of fuel in the wings, and a typical Basic Aricraft Weight of 91,000 pounds, the aricraft can only carry 20,000 pounds of cargo or fuel in the fuselage. The arcraft burns between 4,000 and 6,000 pounds of fuel per hour, and maintains 6,000 pounds of fuel for emergency use. The fuel required will also depend on the time spent on the ground with engines running, the flight time requirements, and weather / alternate requirements.

[25] Department of the Navy, Naval Air Systems Command. *NATOPS Flight Manual: Navy Model MV22 Tiltrotor.* p. I-2-163

[26] The CH-53D has a 12,000-pound lift capacity, but will not be included in this discussion due to the fielding of the CH-53E.
[27] Department of the Navy, Naval Air Systems Command, NATOPS *Flight Manual: Navy Model CH-53E Helicopter*, p. 1-1
[28] Marine Aviation Weapons and Tactics Squadron One (MAWTS-1). *Combat Aircraft Fundamentals CH-53 (Unclassified//For Official Use Only)*, p. 7-5: " The CH-53 does not typically conduct air delivery operations, due to its ability to transport cargo externally, and the ability to land in remote, austere locations."
[29] CH-46 Natops
[30] Lieutenant Colonel Brian E. O'Connor, USAF, "Strategic Brigade Airdrop: Effects of Army Transformation and Modularity", p 11
[31] Tom Meador, "Cargo Airdrop Overview: Parachute Industry Association Briefing"
[32] Marine Aviation Weapons and Tactics Squadron One (MAWTS-1). *Combat Aircraft Fundamentals KC-130 (Unclassified//For Official Use Only)*, p. 5-29
[33] Ibid.
[34] The Bell Eagle Eye has a lift capacity of 200 pounds. The Boeing hummingbird has a lift capacity of 300 pounds, and the Fire Scout has a lift capacity of 300 pounds.
[35] Tom Meador, "Cargo Airdrop Overview: Parachute Industry Association Briefing"
[36] The Marine Rifle Company is used as the baseline because this is most likely the smallest unit capable of conducting sustained operations on its own.
[37] Army Logistics Estimate Worksheet/ Operations Logistics Planner developed by the U.S. Army Combined Arms Support Command (CASCOM) Planning Division.
[38] Based on Marine Corps Current Readiness reporting.
[39] Gen James T. Conway, Commandant of the Marine Corps, "A Concept for Enhanced Company Operations"

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Appendix

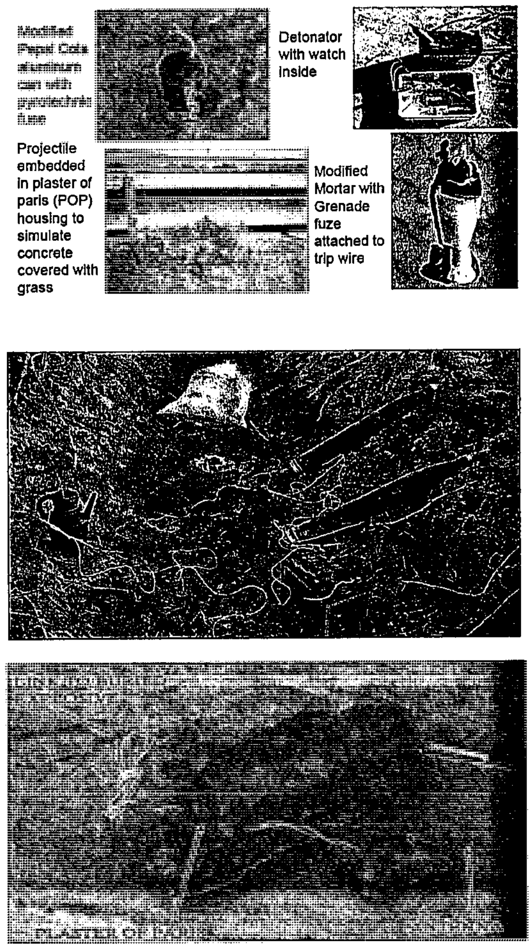

Figure 3: Examples of IEDs Found in Afghanistan and Iraq

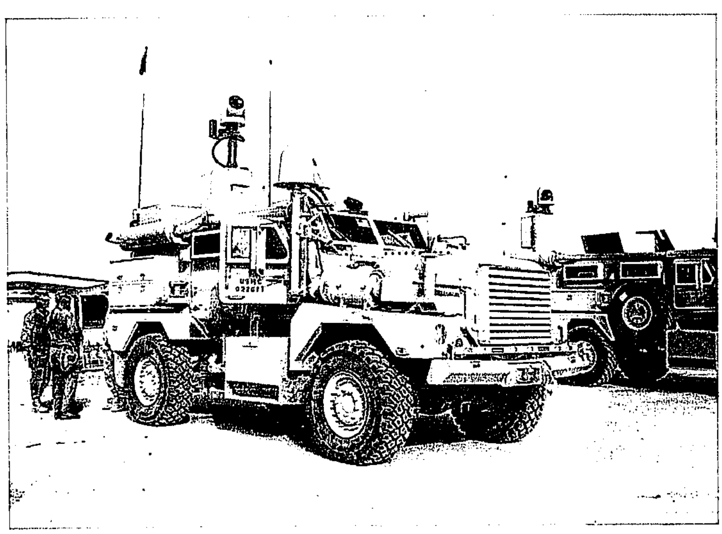

Figure 4: MRAP Cougar

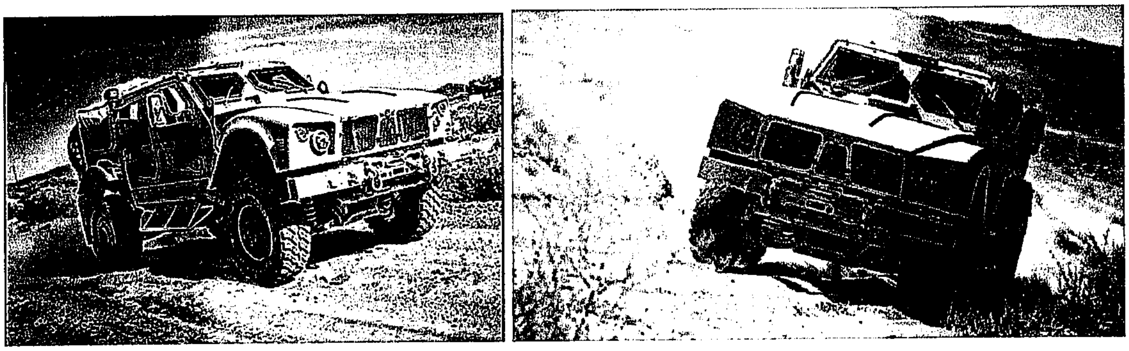

Figure 5: M-ATV

Figure 6: MTVR

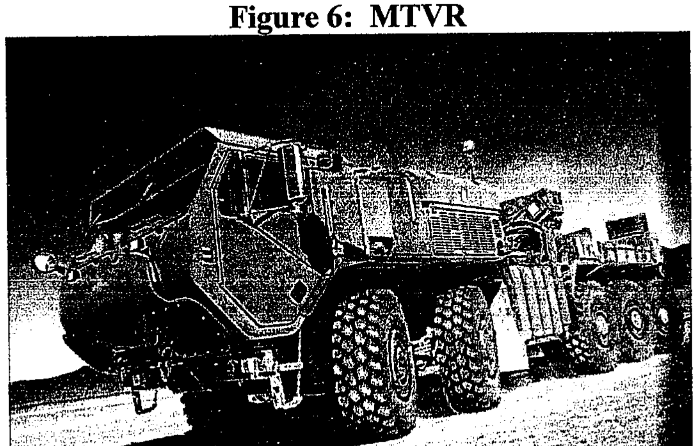

Figure 7: LVSR

Figure 8: Marine Corps KC-130J, CH-53E, MV-22 & CH-46 Aircraft

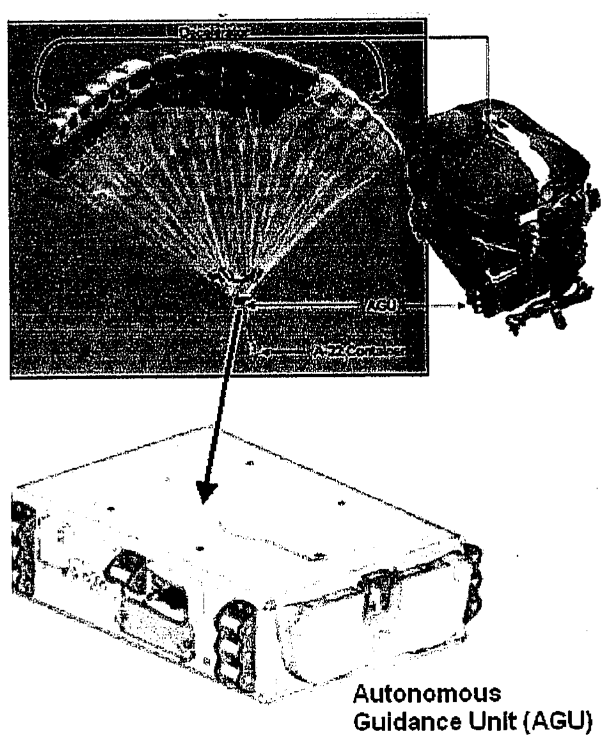

Figure 9: JPADS 2,400-pound Delivery System

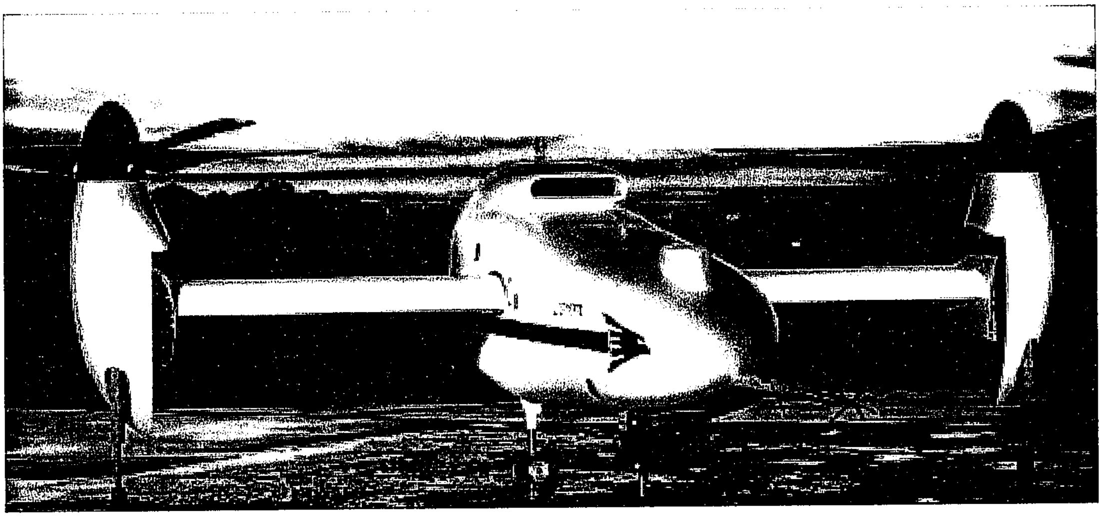

Figure 10: Bell Helicopter "Eagle Eye" Vertical Lift UAS

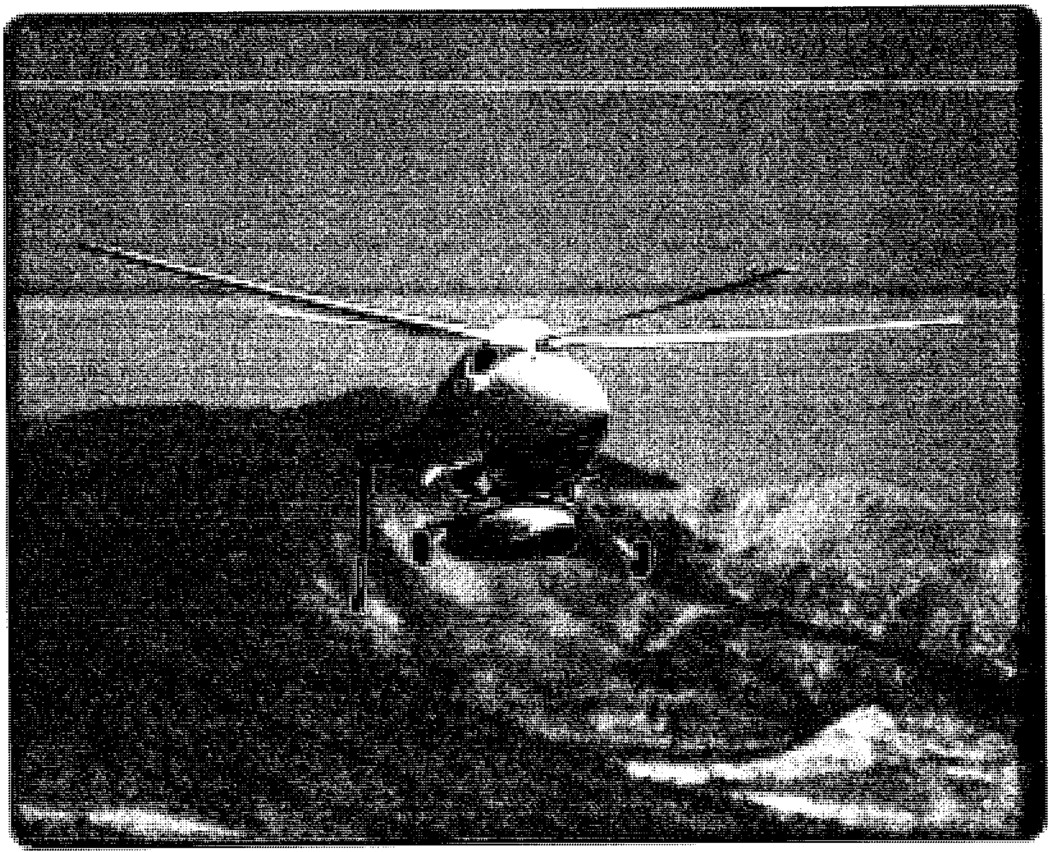

Figure 11: Boeing A160 Hummingbird

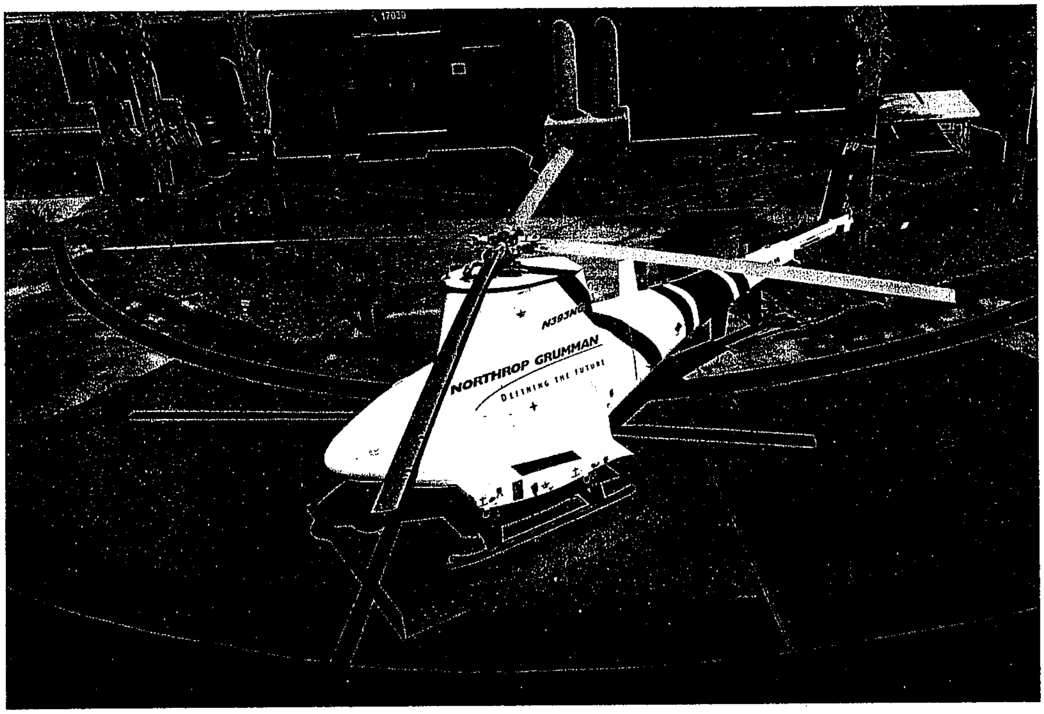

Figure 12: Northrup Grumman Fire Scout

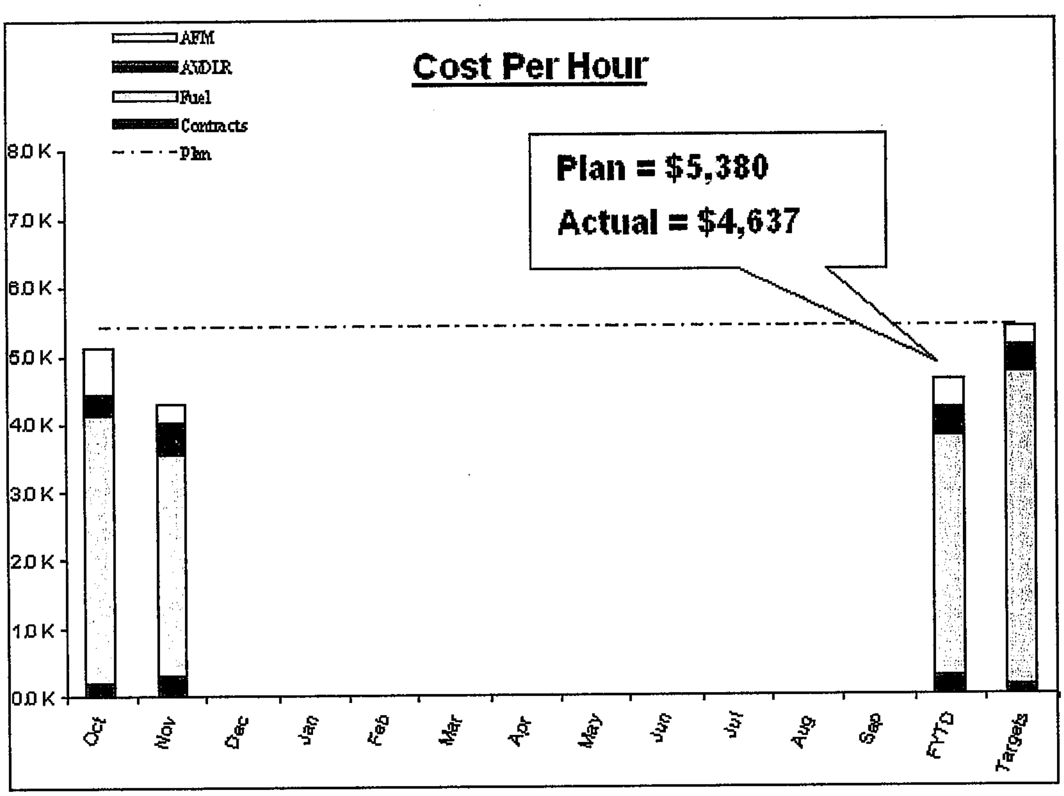

Figure 13: KC-130J November 2008 ACES Cost Chart